The Respiratory System -Anatomy

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LEARNING OUTCOMES

As a result of the lesson you will be able to:

- *Name and locate the organs of the urinary system; and Describe the location and general appearance of the kidneys;*
- *Describe macroscopic and microscopic anatomy of the kidney and Identify them in the model or diagrams ;*
- *List several functions of the kidneys in addition to urine formation;*
- *Trace the flow of blood through the kidney;*
- *Trace the flow of fluid through the renal tubules;*
- *Describe the nerve supply to the kidney.*
- *Describe the morphology and function of the nephron.*
- *Identify the ureters, urinary bladder, and urethra, as well as their location, structure and function*

Waste Products & Kidney Function

- '*to live is to metabolize*', and metabolism creates a variety of toxic waste products

- removed from the body by various systems
  - respiratory, digestive, sweat glands and urinary

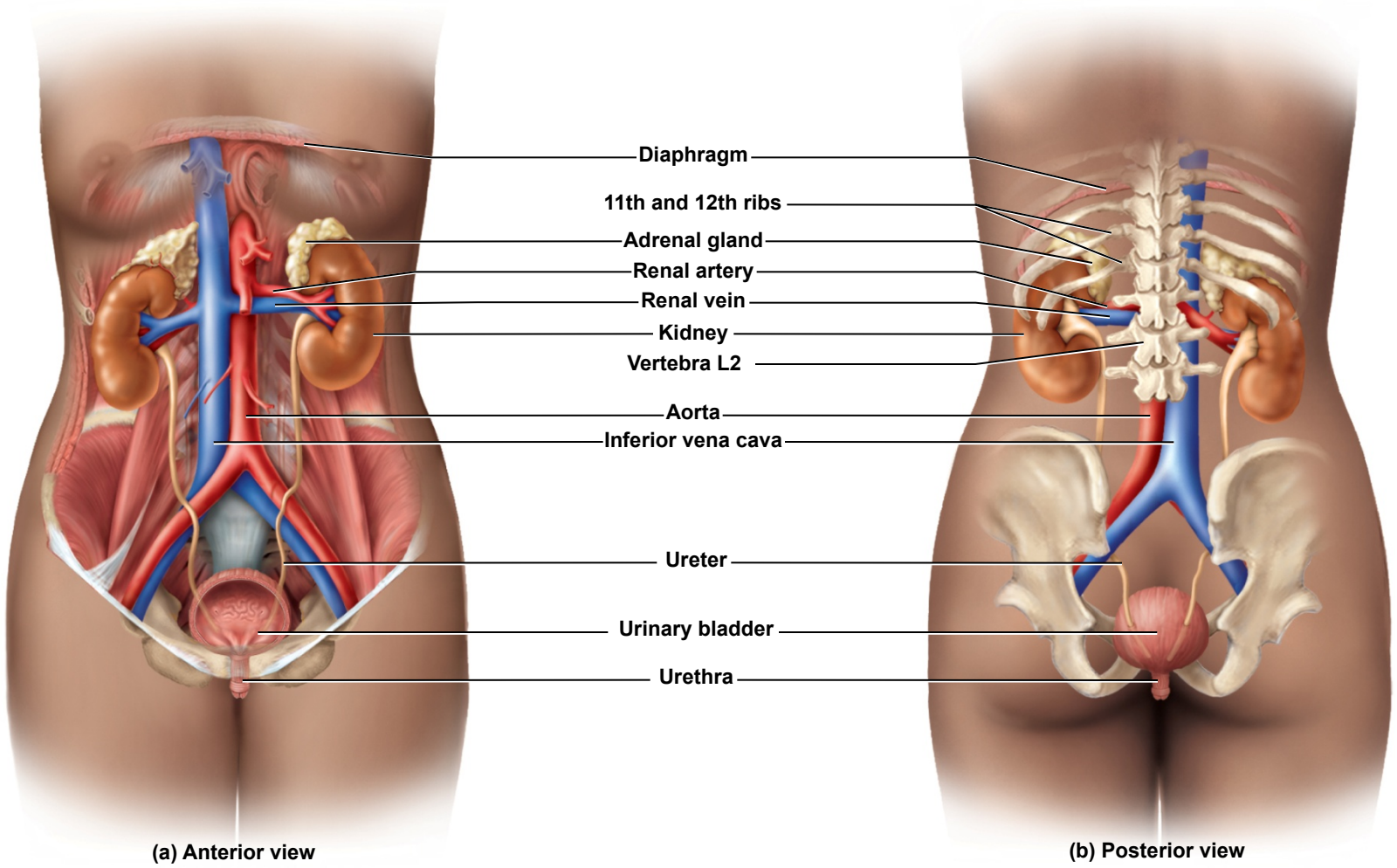
- **urinary system** – principal means of waste removal

- kidney functions
  - regulate blood volume and pressure, erythrocyte count, blood gases, blood pH, and electrolyte and acid base balance

- urinary system is closely associated with reproductive system
  - 'urogenital system'
  - share embryonic development
  - share adult anatomical relationship
  - male urethra serves as a common passage for urine and sperm

- **urologists** – treat both urinary and reproductive disorders

Urinary System



urinary system consists of 6 organs:
2 kidneys, 2 ureters, urinary bladder, and urethra

Figure 23.1a-b

Kidney Location

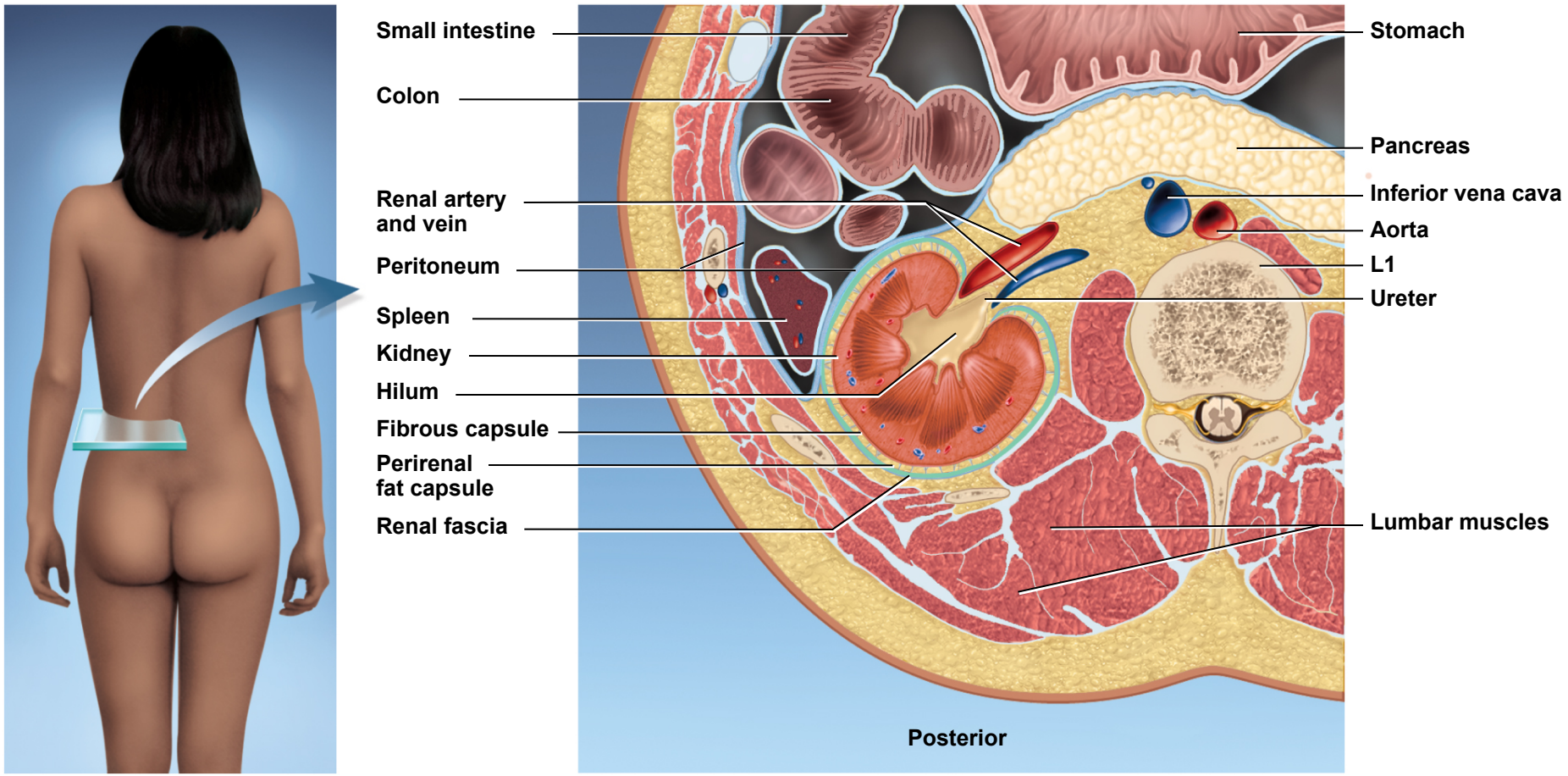


Figure 23.3 a-b

Functions of the Kidney

- filters blood plasma, separates waste from useful chemicals, returns useful substances to blood, **eliminates wastes**
- regulate **blood volume and pressure** by eliminating or conserving water
- regulate the **osmolarity** of the body fluids by controlling the relative amounts of water and solutes eliminated
- secretes enzyme, ***renin***, which activates hormonal mechanisms that control blood pressure and electrolyte balance
- secretes the hormone, ***erythropoietin***, which stimulates the production of red blood cells
- collaborate with the lungs to regulate the P_{CO_2} and **acid-base balance** of body fluids
- final step in synthesizing hormone, ***calcitriol***, which contributes to calcium homeostasis
- **gluconeogenesis** from amino acids in extreme starvation

Nitrogenous Wastes

- **waste** – any substance that is useless to the body or present in excess of the body's needs
- **metabolic waste** – waste substance produced by the body
- **urea formation**
  - proteins→ amino acids → NH_2 removed → forms **ammonia**, liver converts to urea
- **uric acid**
  - product of nucleic acid catabolism
- **creatinine**
  - product of creatine phosphate catabolism
- **blood urea nitrogen (BUN)** – expression of the level of nitrogenous waste in the blood
  - normal concentration of blood urea is 10 – 20 mg/dl
  - **azotemia** – elevated BUN
    - indicates renal insufficiency
  - **uremia** – syndrome of diarrhea, vomiting, dyspnea, and cardiac arrhythmia stemming from the toxicity of nitrogenous waste
    - treatment – hemodialysis or organ transplant

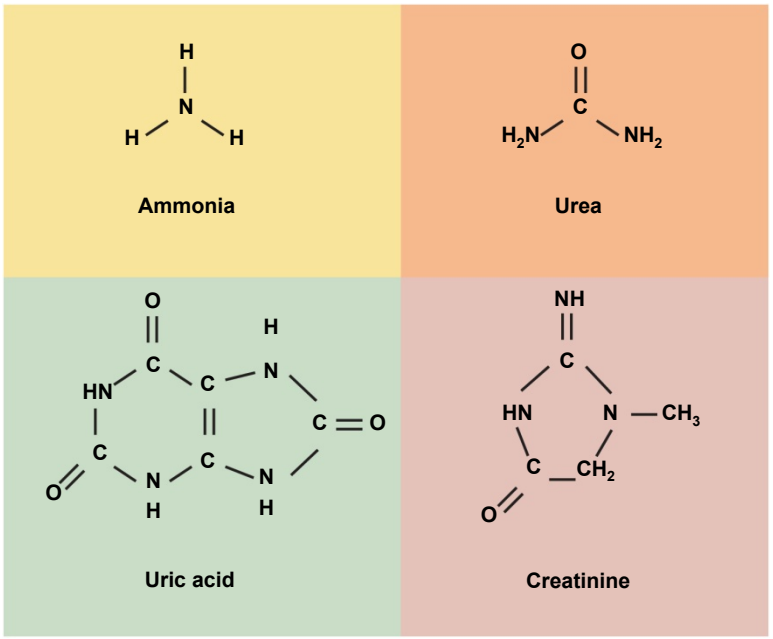


Figure 23.2

Excretion

- **excretion** - separation of wastes from body fluids and eliminating them
- **four body systems** carry out excretion
  - **respiratory system**
    - CO_2 , small amounts of other gases, and water
  - **integumentary system**
    - water, inorganic salts, lactic acid, urea in sweat
  - **digestive system**
    - water, salts, CO_2, lipids, bile pigments, cholesterol, other metabolic waste, and food residue
  - **urinary system**
    - many metabolic wastes, toxins, drugs, hormones, salts, H^+ and water

Anatomy of Kidney

- position, weight and size
  - lie against posterior abdominal wall at level of T12 to L3
  - right kidney is slightly lower due to large right lobe of liver
  - rib 12 crosses the middle of the left kidney
  - **retroperitoneal** along with ureters, urinary bladder, renal artery and vein, and adrenal glands
- shape and size
  - about size of bar of bath soap
  - lateral surface is convex and medial is concave with a slit, **hilum**
    - receives renal nerves, blood vessels, lymphatics, and ureter
- three protective connective tissue coverings
  - **renal fascia** immediately deep to parietal peritoneum
    - binds it to abdominal wall
  - **perirenal fat capsule -** cushions kidney and hold it into place
  - **fibrous capsule** encloses kidney protecting it from trauma and infection
    - collagen fibers extend from fibrous capsule to renal fascia
    - still drop about 3 cm when go from lying down to standing up

Gross Anatomy of Kidney

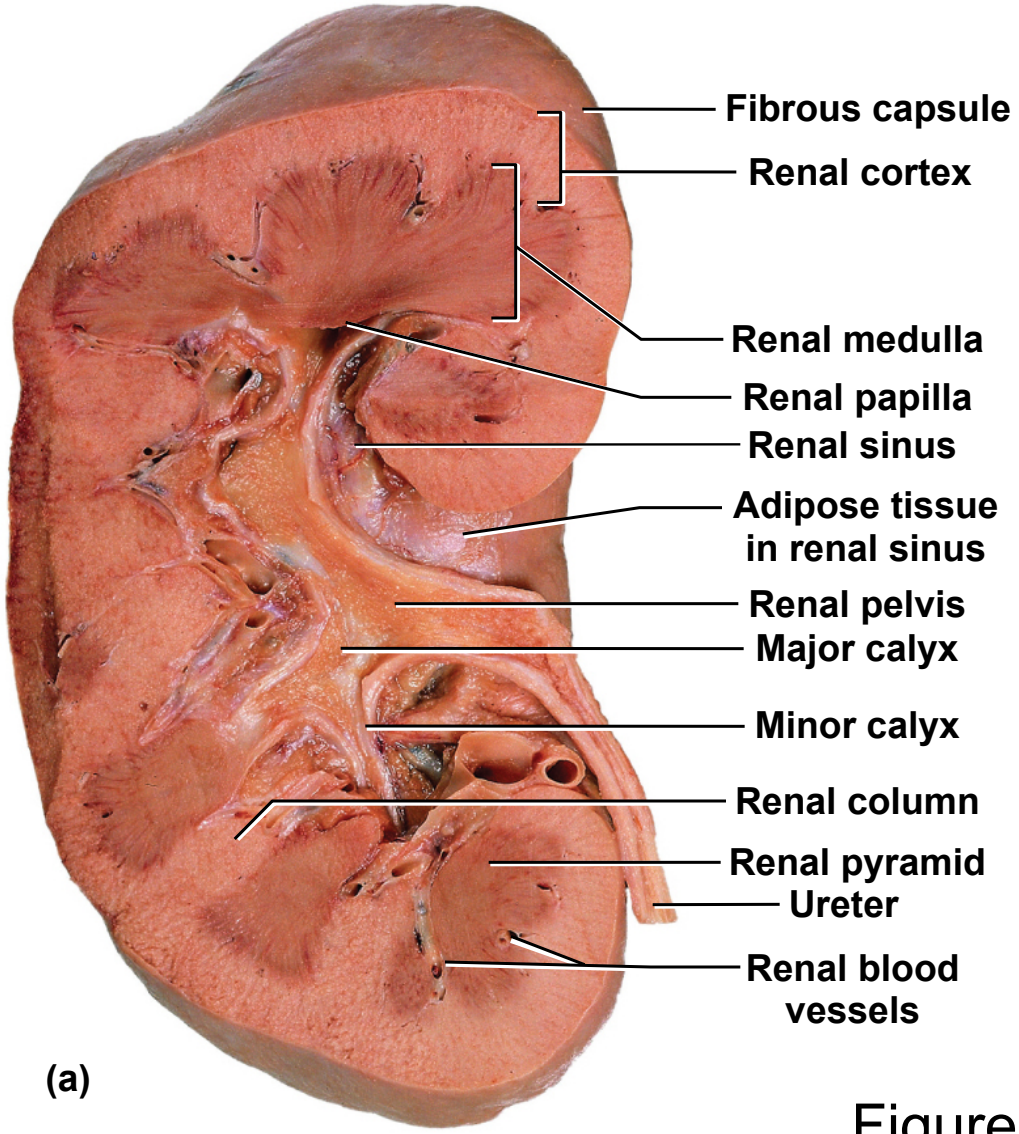


Figure 23.4a

Ralph Hutchings/Visuals Unlimited

Anatomy of Kidney

- **renal parenchyma** – glandular tissue that forms urine
  - appears C-shaped in frontal section
  - encircles the renal sinus
  - **renal sinus** – contains blood and lymphatic vessels, nerves, and urine-collecting structures
    - adipose fills the remaining cavity and holds structures into place

- **two zones of renal parenchyma**
  - outer **renal cortex**
  - inner **renal medulla**
    - **renal columns** – extensions of the cortex that project inward toward sinus
    - **renal pyramids** – 6 to 10 with broad base facing cortex and renal papilla facing sinus
  - **lobe of the kidney** – one pyramid and its overlying cortex
  - **minor calyx** – cup that nestles the papilla of each pyramid
    - collects its urine
  - **major calyces** - formed by convergence of two or three minor calyces
  - **renal pelvis** – formed by convergence of two or three major calyces
  - **ureter** - a tubular continuation of the pelvis and drains the urine down to the urinary bladder

Anatomy of Kidney

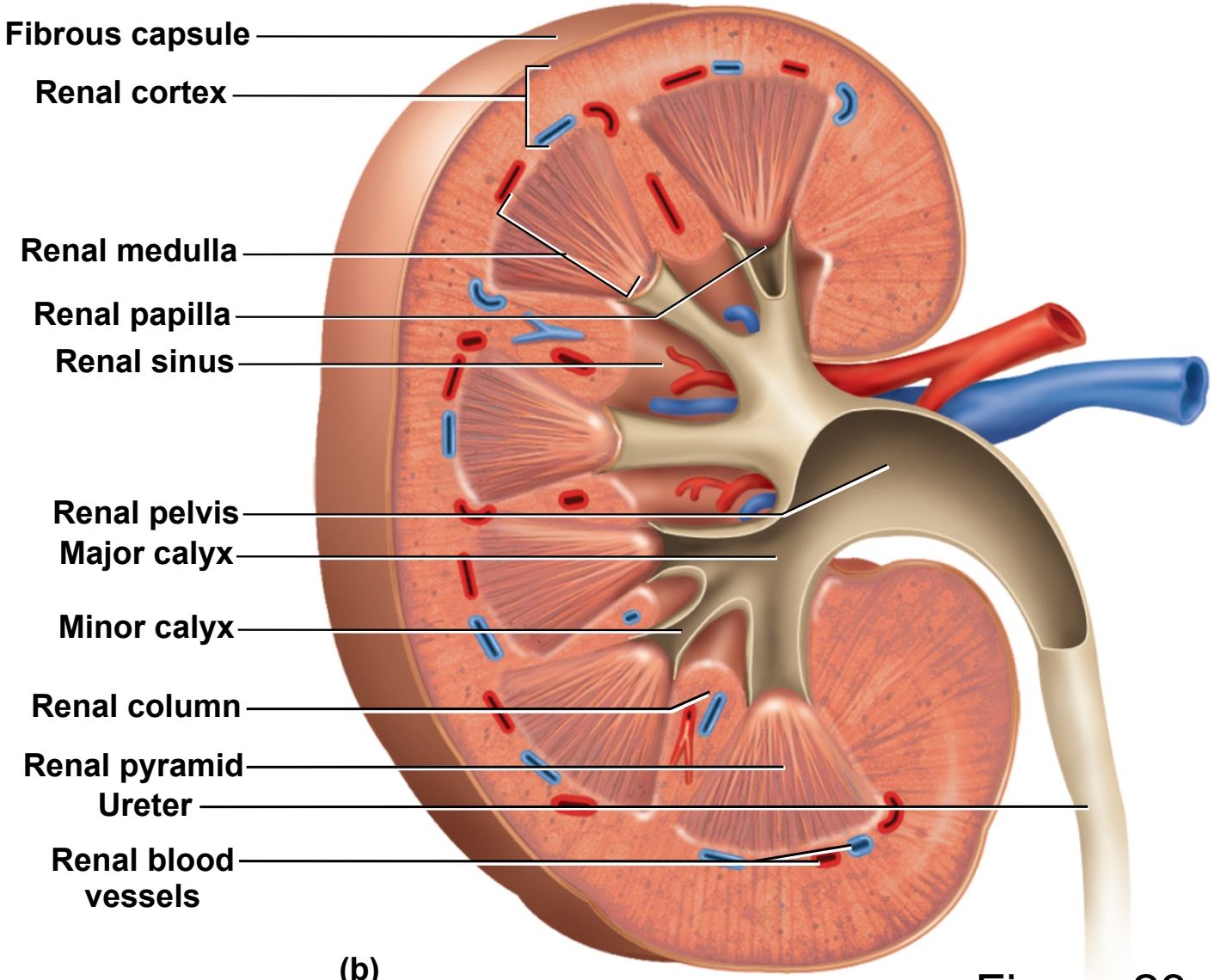
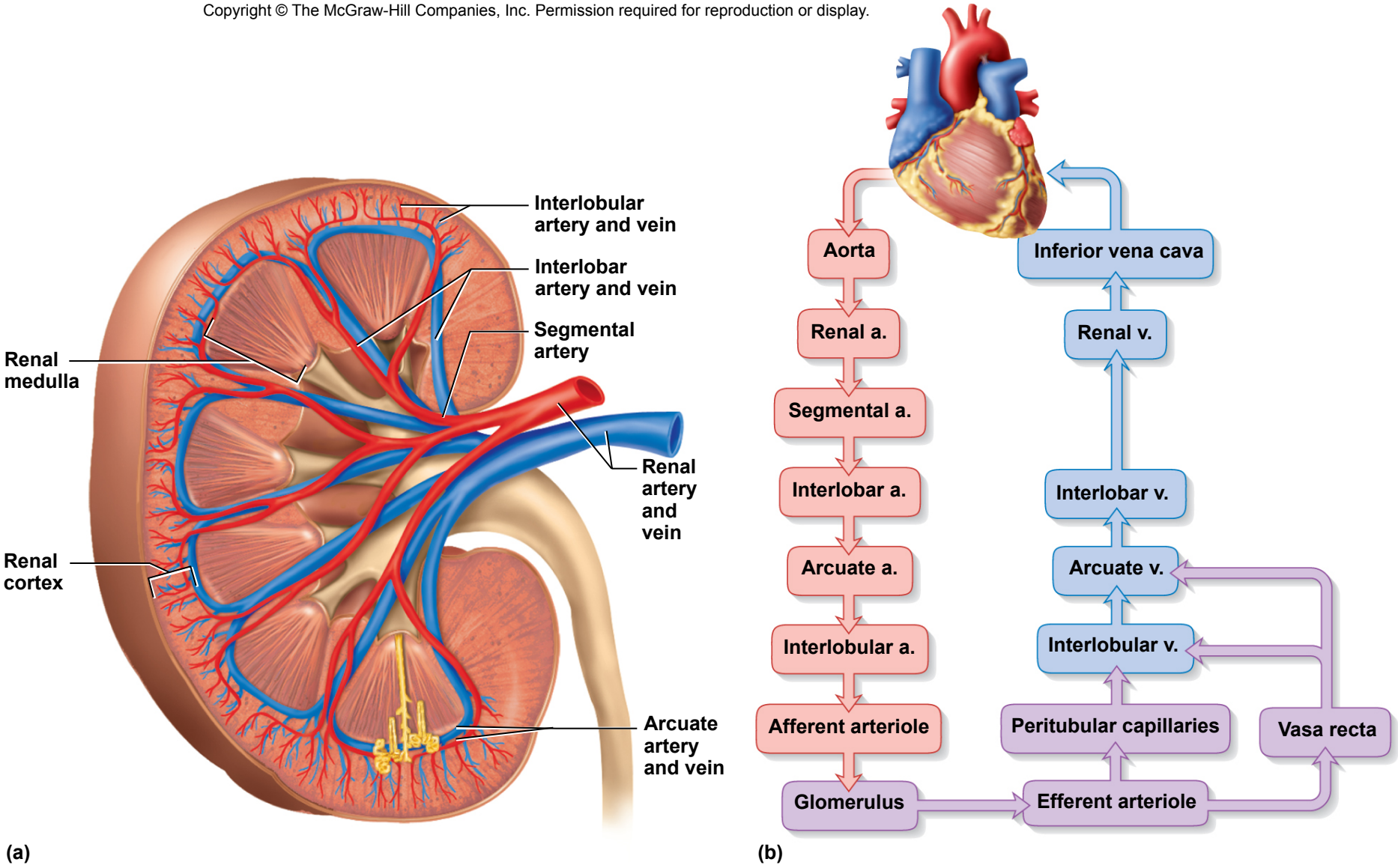


Figure 23.4b

Blood Supply Diagram



kidneys receive 21% of cardiac output

Figure 23.5 a-b

Renal Circulation

- kidneys account for only 0.4% of body weight, they receive about 21% of the cardiac output (**renal fraction**)

- **renal artery** divides into **segmental arteries** that give rise to
  - **interlobar arteries** - up renal columns, between pyramids
  - **arcuate arteries** - over pyramids
  - **interlobular arteries** - up into cortex
  - branch into **afferent arterioles -** each supplying **one nephron**
    - leads to a ball of capillaries - **glomerulus**
  - blood is drained from the glomerulus by **efferent arterioles**
  - lead to either **peritubular capillaries** or **vasa recta** around portion of the renal tubule
  - **interlobular veins** or directly into **arcuate veins** - **interlobar veins**

- **renal vein** empties into **inferior vena cava**

Microcirculation of the Kidney

- in the cortex, **peritubular capillaries** branch off of the efferent arterioles supplying the tissue near the glomerulus, the proximal and distal convoluted tubules

- in medulla, the efferent arterioles give rise to the **vasa recta,** supplying the nephron loop portion of the nephron.

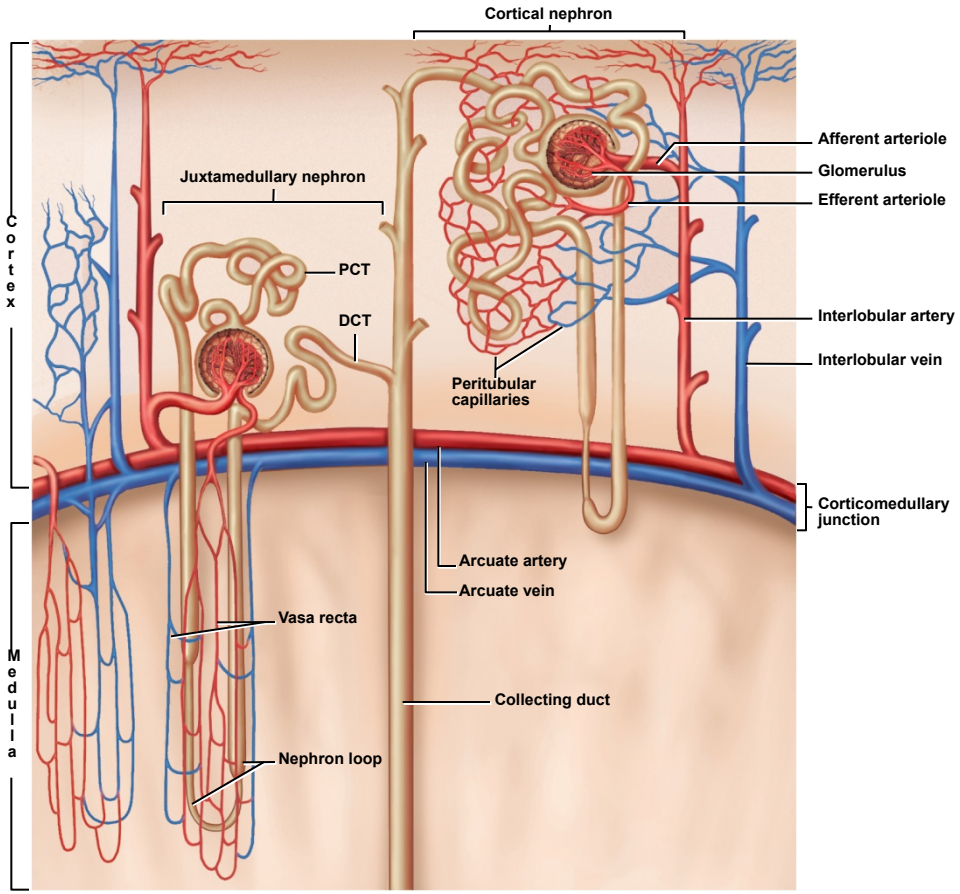


Figure 23.6

The Nephron

- each kidney has about 1.2 million nephrons

- each composed of two principal parts:
  - **renal corpuscle** – filters the blood plasma
  - **renal tubule** – long coiled tube that converts the filtrate into urine

- **renal corpuscle** consists of the **glomerulus** and a two-layered **glomerular (Bowman) capsule** that encloses glomerulus
  - **parietal (outer) layer of Bowman capsule** is simple squamous epithelium
  - **visceral (inner) layer of Bowman capsule** consists of elaborate cells called **podocytes** that wrap around the capillaries of the glomerulus
  - **capsular space** separates the two layers of Bowman capsule

- **vascular pole** – the side of the corpuscle where the afferent arterial enter the corpuscle and the efferent arteriole leaves

- **urinary pole** – the opposite side of the corpuscle where the renal tubule begins

Renal Corpuscle

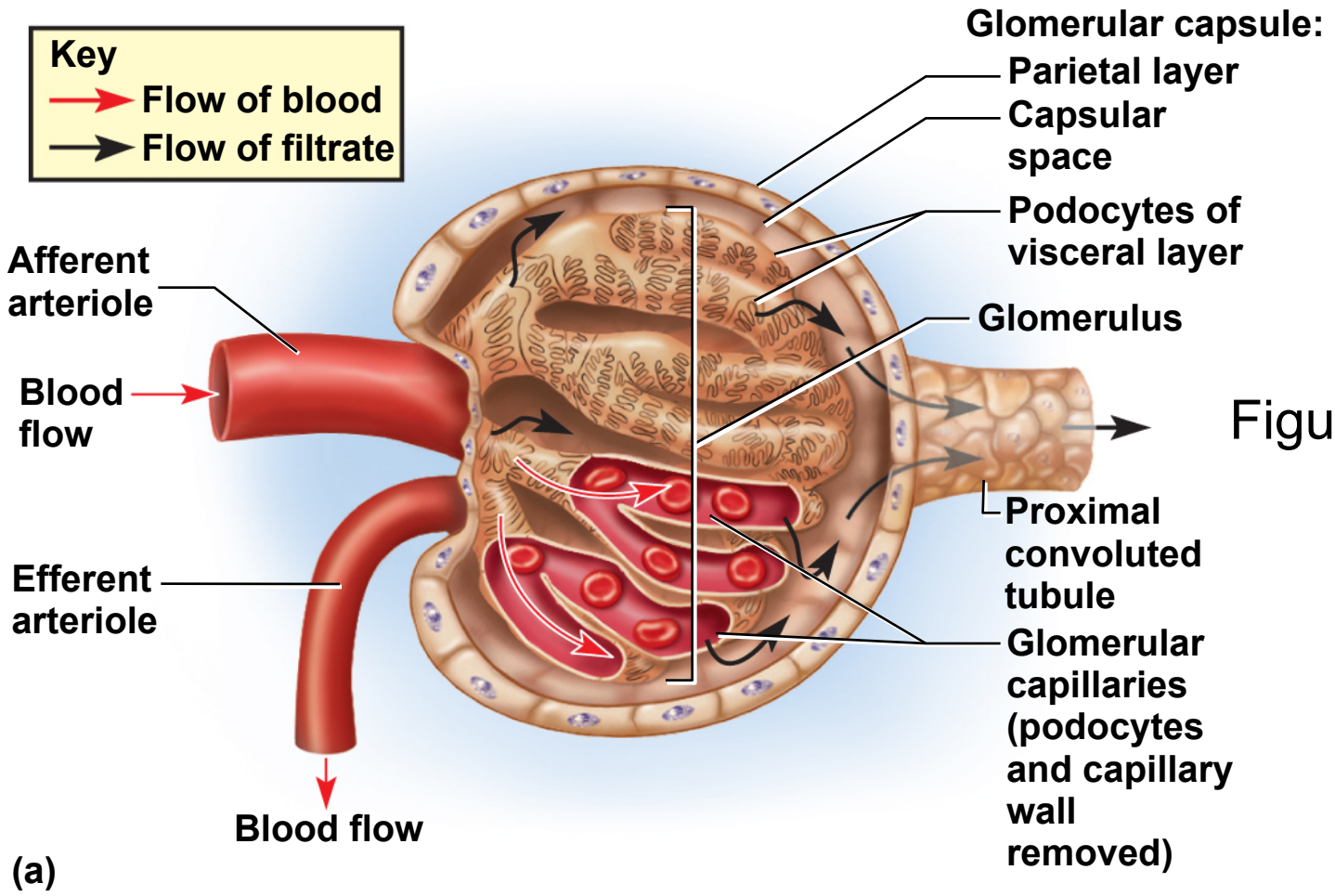


Figure 23.7a

- glomerular filtrate collects in capsular space, flows into proximal convoluted tubule. Note the vascular and urinary poles. Note the afferent arteriole is larger than the efferent arteriole.

Renal Tubule

- **renal (uriniferous) tubule** – a duct that leads away from the glomerular capsule and ends at the tip of the medullary pyramid

- **divided into four regions** –
  - ***proximal convoluted tubule***, ***nephron loop***, ***distal convoluted tubule*** – parts of one nephron
  - ***collecting duct*** receives fluid from many nephrons

- **proximal convoluted tubule** (PCT) – arises from glomerular capsule
  - longest and most coiled region
  - simple cuboidal epithelium with **prominent microvilli** for majority of absorption

- **nephron loop (loop of Henle)** – long U-shaped portion of renal tubule
  - descending limb and ascending limb
  - **thick segments** have simple cuboidal epithelium
    - initial part of descending limb and part or all of the ascending limb
    - heavily engaged in the active transport of salts and have many mitochondria
  - **thin segment** has simple squamous epithelium
    - forms lower part of descending limb
    - cells very permeable to water

Renal Tubule

- **distal convoluted tubule** (DCT) – begins shortly after the ascending limb reenters the cortex
  - shorter and less coiled that PCT
  - cuboidal epithelium without microvilli
  - DCT is the end of the nephron
- **collecting duct** – receives fluid from the DCTs of several nephrons as it passes back into the medulla
  - numerous collecting ducts converge toward the tip of the medullary pyramid
  - **papillary duct** – formed by merger of several collecting ducts
    - 30 papillary ducts end in the tip of each papilla
    - collecting and papillary ducts lined with simple cuboidal epithelium
- flow of fluid from the point where the glomerular filtrate is formed to the point where urine leaves the body:

  glomerular capsule → proximal convoluted tubule → nephron loop → distal convoluted tubule → collecting duct → papillary duct → minor calyx → major calyx → renal pelvis → ureter → urinary bladder → urethra

The Nephron

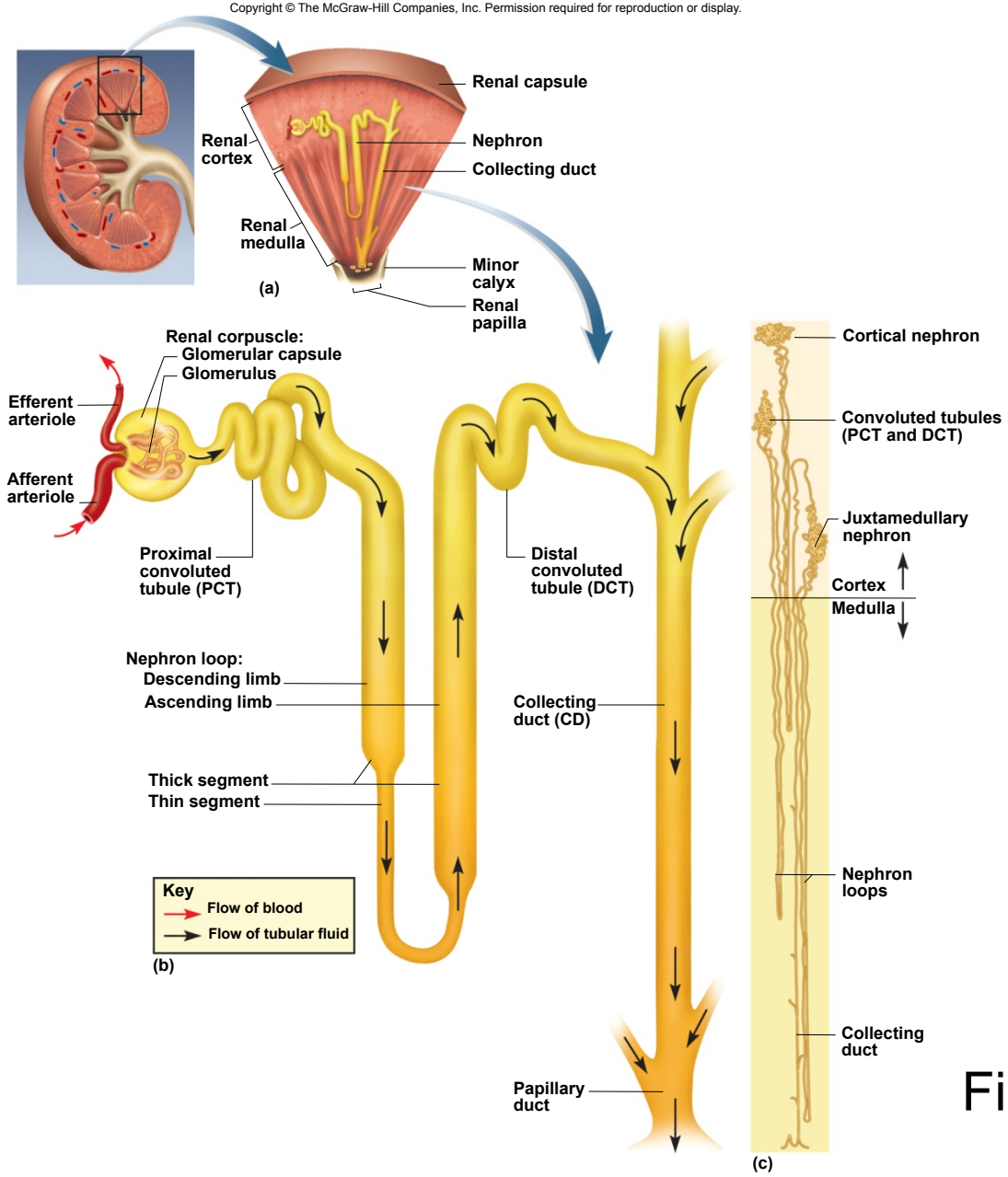


Figure 23.8

Cortical and Juxtamedullary Nephrons

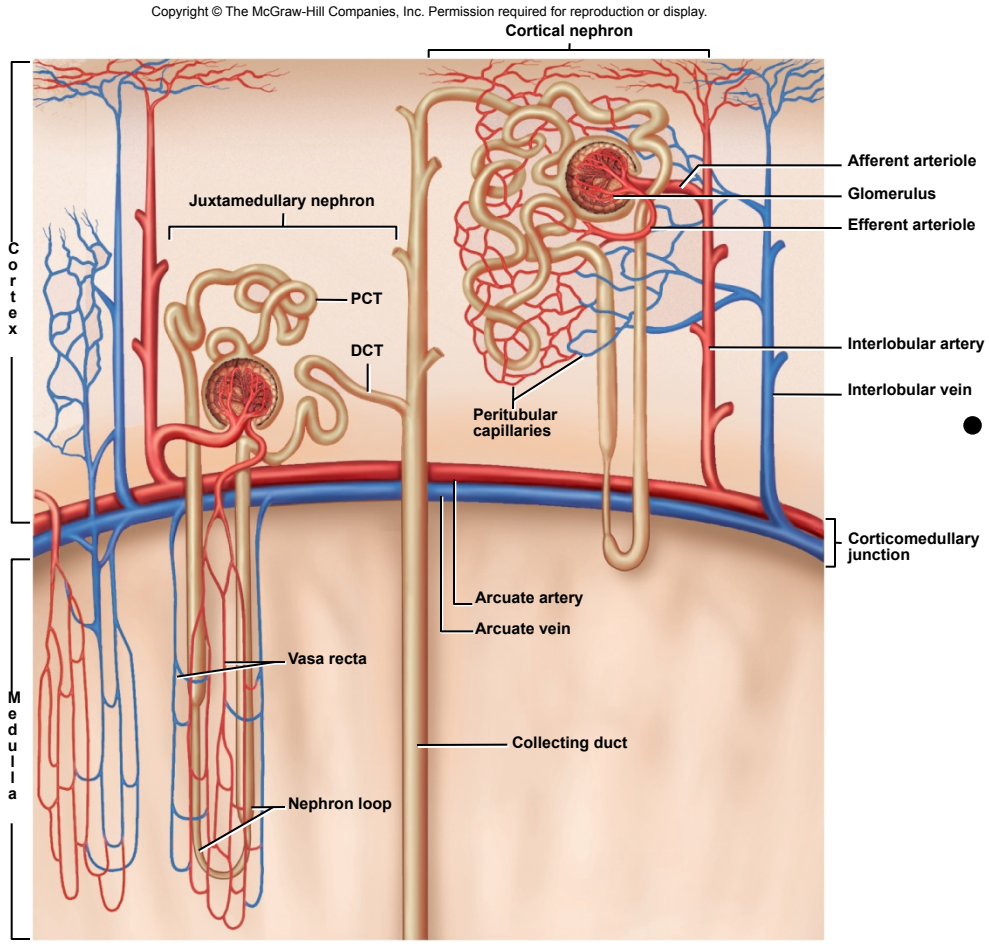


Figure 23.6

- **cortical nephrons**
  - 85% of all nephrons
  - short nephron loops
  - efferent arterioles branch into **peritubular capillaries** around PCT and DCT
- **juxtamedullary nephrons**
  - 15% of all nephrons
  - very long nephron loops, maintain salinity gradient in the medulla and helps conserve water
  - efferent arterioles branch into **vasa recta** around long nephron loop

Renal Innervation

- **renal plexus** – nerves and ganglia wrapped around each renal artery
  - follows branches of the renal artery into the parenchyma of the kidney
  - issues nerve fibers to the blood vessels and convoluted tubules of the nephron
  - carries **sympathetic** innervation from the abdominal aortic plexus
    - stimulation reduces glomerular blood flow and rate of urine production
    - respond to falling blood pressure by stimulating the kidneys to secrete ***renin***, an enzyme that activates hormonal mechanisms to restore blood pressure
  - carries **parasympathetic** innervation from the vagus nerve – increases rate of urine production

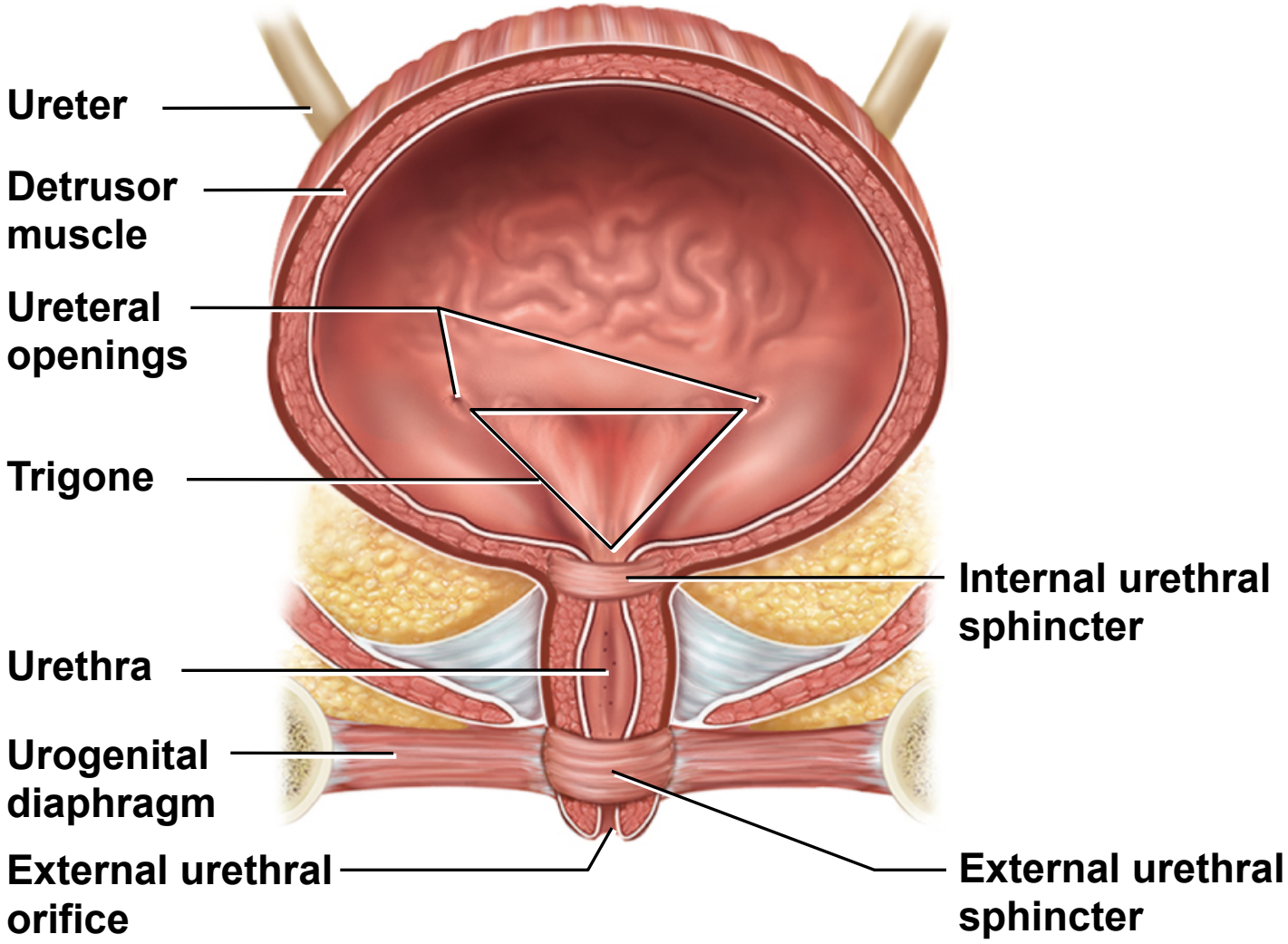
The Ureter

- **ureters** – retroperitoneal, muscular tube that extends from the **kidney to the urinary bladder**
  - about 25 cm long
  - passes posterior to bladder and enters it from below
  - flap of mucosa acts as a valve into bladder
    - keeps urine from backing up in the ureter when bladder contracts
  - 3 layers of ureter
    - **adventitia** – connective tissue layer that connects ureter to surrounding structures
    - **muscularis** - 2 layers of smooth muscle with 3rd layer in lower ureter
      - urine enters, it stretches and contracts in peristaltic wave
    - **mucosa** - transitional epithelium
      - begins at minor calyces and extends through the bladder
  - lumen very narrow, easily obstructed kidney stones

Urinary Bladder

- **urinary bladder** - muscular sac located on floor of pelvic cavity
  - inferior to peritoneum and posterior to pubic symphysis
- **3 layers**
  - parietal peritoneum, superiorly, fibrous adventitia other areas
  - muscularis - **detrusor muscle** - 3 layers of smooth muscle
  - mucosa - transitional epithelium
    - **rugae** - conspicuous wrinkles in relaxed bladder
- **trigone** – smooth-surfaced triangular area marked with openings of ureters and urethra
- capacity - mod. full is 500 ml, max. is 700 - 800 ml
  - highly distensible
  - as it fills, it expands superiorly
  - rugae flatten
  - epithelium thins from five or six layers to two or three

Urinary Bladder



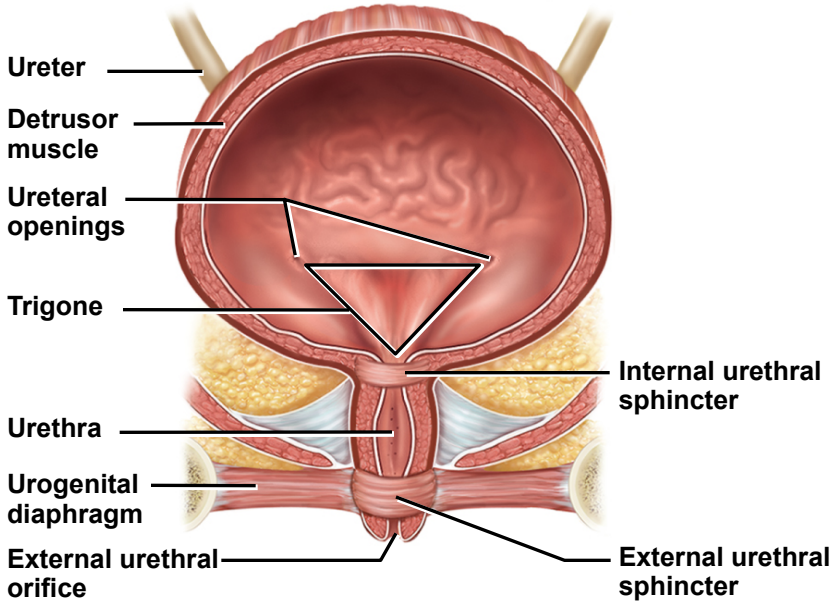
(a) Female

Figure 23.23a

Kidney Stones

- **renal calculus (kidney stone)** - hard granule of calcium phosphate, calcium oxalate, uric acid, or a magnesium salt called **struvite**
- form in the renal pelvis
- usually small enough to pass unnoticed in the urine flow
  - large stones might block renal pelvis or ureter and can cause pressure build up in kidney which destroys nephrons
    - passage of large jagged stones is excruciatingly painful and may damage ureter causing hematuria
- **causes** include hypercalcemia, dehydration, pH imbalances, frequent urinary tract infections, or enlarged prostate gland causing urine retention
- **treatment** includes stone dissolving drugs, often surgery, or **lithotripsy** –nonsurgical technique that pulverizes stones with ultrasound

Female Urethra

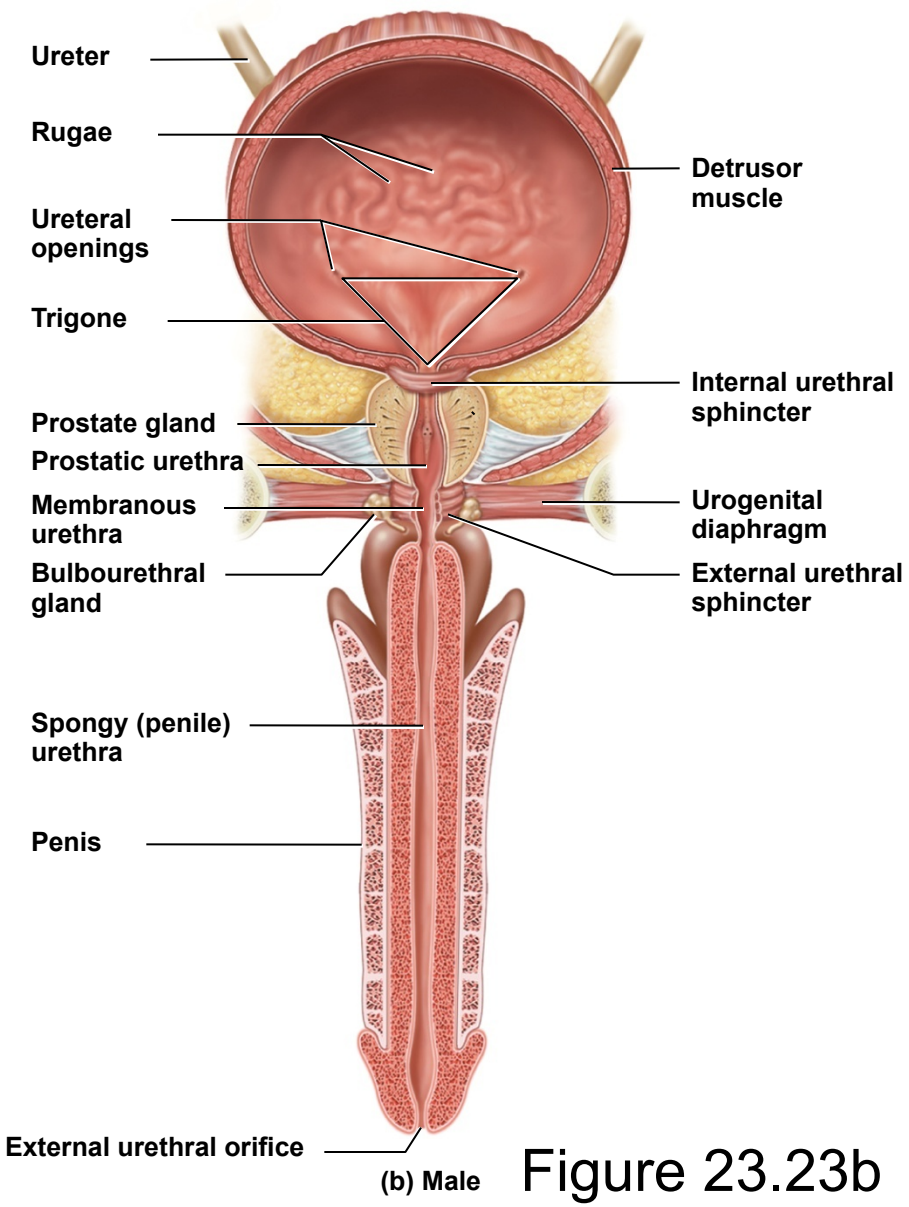


(a) Female

Figure 23.23a

- 3 to 4 cm long
- bound to anterior wall of vagina
- **external urethral orifice**
  - between vaginal orifice and clitoris
- **internal urethral sphincter**
  - detrusor muscle thickening
  - smooth muscle under involuntary control
- **external urethral sphincter**
  - where the urethra passes through the pelvic floor
  - skeletal muscle under voluntary control

Male Urethra



- 18 cm long
- 3 regions of male urethra
  - **prostatic urethra** (2.5 cm)
    - passes through prostate gland
  - **membranous urethra** (.5 cm)
    - passes through muscular floor of pelvic cavity
  - **spongy (penile) urethra** (15 cm)
    - passes through penis in corpus spongiosum
- **internal urethral sphincter**
  - detrusor muscle thickening
- **external urethral sphincter**
  - part of skeletal muscle of pelvic floor

Figure 23.23b

Urinary Tract Infection (UTI)

- **cystitis** – infection of the urinary bladder
  - especially common in females due to short urethra
  - frequently triggered by sexual intercourse
  - can spread up the ureter causing pyelitis
- **pyelitis** – infection of the renal pelvis
- **pyelonephritis** – infection that reaches the cortex and the nephrons
  - can result from blood-borne bacteria

Voiding Urine

- between acts of urination, the bladder is filling
  - **detrusor** muscle relaxes
  - **urethral sphincters** are tightly closed
    - accomplished by sympathetic pathway from upper lumbar spinal cord
    - postganglionic fibers travel through the hypogastric nerve to the detrusor muscle (*relax*) and internal urethral sphincter (*excite*)
  - **somatic motor fibers** from upper sacral spinal cord through pudendal nerve to supply the **external sphincter** give us voluntary control
- **micturition** – the act of urinating
- **micturition reflex** - spinal reflex that partly controls urination

Voiding Urine – Micturition Reflex

- **involuntary control** (steps 1 – 4)
  - filling of the bladder to about 200 mL excites stretch receptors in the bladder wall
  - send sensory signals through fibers in pelvic nerve to sacral spinal cord (S_2 or S_3)
  - motor signals travel back from the spinal cord to the bladder by way of motor fibers in pelvic nerve and parasympathetic ganglion in bladder wall
  - excites detrusor muscle and relaxes internal urethral sphincter
  - results in emptying bladder
  - if there was no voluntary control over urination, this reflex would be the only means of control

Voiding Urine – Micturition Reflex

- **voluntary control** (steps 5 – 8)
  - **micturition center** - nucleus in the pons that receives some input from bladder stretch receptors that ascends the spinal cord
  - nucleus integrates information about bladder tension with information from other brain centers
    - urination can be prompted by fear
    - inhibited by knowledge that the circumstances are inappropriate for urination
  - fibers from micturition center descend the spinal cord
    - through reticulospinal tracts
  - some fibers inhibit sympathetic fibers than normally keep internal urethral sphincter contracted
  - others descend farther to sacral spinal cord
    - excite parasympathetic neurons that stimulate the detrusor to contract and relax the internal urethral sphincter
  - initial detrusor contraction raises pressure in bladder, stimulate stretch receptors, bringing about more forceful contraction
  - external urethral sphincter receives nerve fibers from cerebral cortex by way of corticospinal tract
    - inhibit somatic motor neurons that normally keep that sphincter constricted

Voiding Urine – Micturition Reflex

- urge to urinate usually arises at an inconvenient time
  - one must suppress it
  - stretch receptors fatigue and stop firing
- as bladder tension increases
  - signals return with increasing frequency and persistence
- there are times when the bladder is not full enough to trigger the micturition reflex but one wishes to ‘go’ anyway
  - **Valsalva maneuver** used to compress bladder
  - excites stretch receptors early getting the reflex started

Neural Control of Micturition

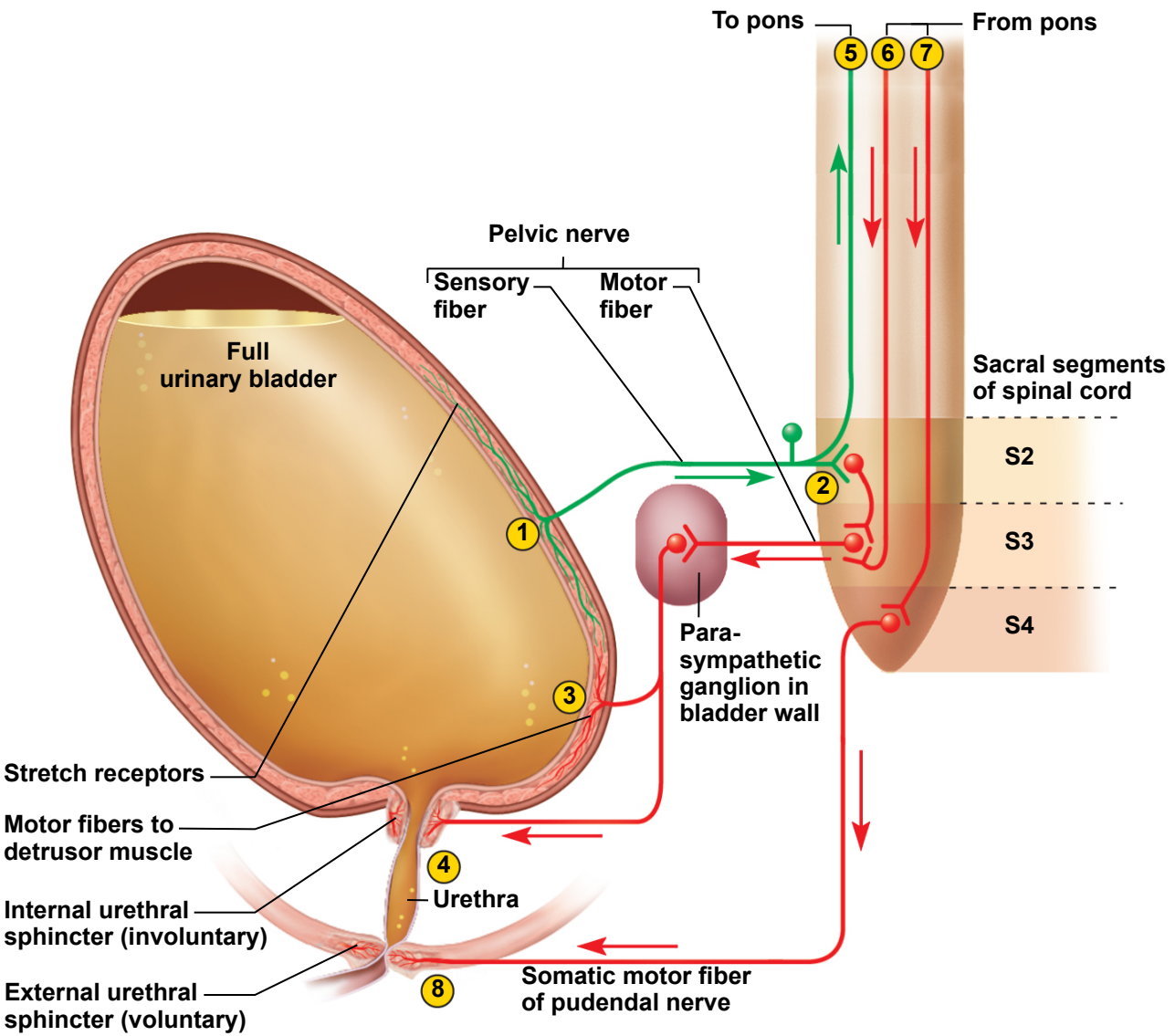


Figure 23.24

Involuntary micturition reflex

1. Stretch receptors detect filling of bladder, transmit afferent signals to spinal cord.
2. Signals return to bladder from spinal cord segments S2 and S3 via parasympathetic fibers in pelvic nerve.
3. Efferent signals excite detrusor muscle.
4. Efferent signals relax internal urethral sphincter. Urine is involuntarily voided if not inhibited by brain.

Voluntary control

5. For voluntary control, micturition center in pons receives signals from stretch receptors.
6. If it is timely to urinate, pons returns signals to spinal interneurons that excite detrusor and relax internal urethral sphincter. Urine is voided.
7. If it is untimely to urinate, signals from pons excite spinal interneurons that keep external urethral sphincter contracted. Urine is retained in bladder.
8. If it is timely to urinate, signals from pons cease and external urethral sphincter relaxes. Urine is voided.